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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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Improved mixers with a plurality of local oscillators and systems based thereon

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DESCRIPTION

IMPROVED MIXERS WITH A PLURALITY OF LOCAL OSCILLATORS AND SYSTEMS BASED THEREON

Field of the invention

The present invention concerns mixers with local oscillators (LO) and systems based thereon. More particularly, this invention relates to spurious-reject mixers well suited for use in receivers, in particular for radio frequency signal receivers. The invention also pertains to quadrature mixers.

Background of the invention

Mixers are key elements and critical building blocks indispensable in almost all communication systems such as Global System for Mobile communication (GSM) systems, Blue tooth systems, and Universal Mobile Telephony Systems (UMTS), for example. The mixers are employed in order to realize frequency translation of the carried signal (herein referred to as information signal). This frequency translation is performed by multiplying two signals, and possibly their harmonics.

In the receiver path 10 of a conventional receiver, for example, down conversion mixers are employed that have two distinct different paths, as illustrated in Fig. 1: a radio frequency (RF) port 11 and a local oscillator (LO) port 12. The mixer 13 multiplies the two signals applied to the ports 11 and 12. A low-pass filter (LPF) 14 at the output side of the mixer 13 provides for a filtering of the signal after the multiplication. In Fig. 2A, RF signals are shown that have a first band (referred to as desired signal or desired band) where an information signal is carried by a carrier signal with frequency ω_{RF}. In addition to this first band there are two other spurious bands (also referred to as spurious bands or side bands) at higher frequencies. The spectrum of the LO signal that is applied to the port 12 is illustrated in Fig. 2B. This signal is tuned to the carrier frequency ω_{RF}

of the desired RF signal. At the same time, the LO signal has higher order harmonics. In Fig. 2B, the 3rd order and 5th order harmonics of the LO signal are depicted. At the output side of the filter 14, the intermediate frequency (IF) signal comprises the desired signal plus the signals of the spurious bands. In Fig. 2C this is illustrated in that the signals of the three bands overlap around zero. In such a case, it is not possible for the receiver to discriminate information carried by the desired signal from information carried by the spurious bands.

Mixers can be either passive or active. Passive mixers are simpler, achieve higher linearity and speed, but do not provide any gain. By contrast, active mixers provide considerable gain, so that the noise contribution by the subsequent stages can be reduced. For these reasons, passive mixers find application in microwave and base station circuits, while active mixers are widely used in RF systems.

The LO signal of practical mixers, no matter what type they are, is a square wave. Controlled by a LO signal of a square wave, the output A of a passive mixer is equal to the RF input when the transistor switch in the mixer is on, and the output A is zero when this switch is off. Therefore, the operation of passive mixers can be viewed as a multiplication of the RF signal at port 11 by a rectangular waveform at port 12.

Active mixers, such as a Gibert cell, employ a switching transistor pair (e.g. MOS transistors) for current commutation, where a transconductance stage is used to convert the input voltage signal at the RF port 11 to a current, which is then commutated with the switching transistor pair, controlled by the LO signal at the LO port 12. In order to minimize the circuit noise and achieve the best noise figure, it is desirable to have a square wave LO signal with 50% duty cycle to turn on and off the switch as abruptly as possible.

In most treatments, the mixing operation is considered just as a multiplying of the RF input by a sinusoidal LO signal. Under this simplification, the output spectrum of the mixer contains only two second-order products: the difference $\omega_{RF} - \omega_{LO}$ and the sum $\omega_{RF} + \omega_{LO}$. In receivers, the former is the desired IF frequency, ω_{IF}, while the latter is rejected by a bandpass filter or lowpass filter 14 (LPF) following the mixer 13. As will be shown next, such a treatment is too simple and rough in order to improve the performance of existing mixers.

Details about mixers are given in the book with title "RF Microelectronics", by Behzad Razavi, Prentice Hall, 1998 (ISBN 0-13-887571-5), for example. There are many other publications about mixers.

Because the LO signal of practical mixers is a square wave and not a sine wave, a square wave rather than sine wave has to be used for analysis and design. When a square wave signal is applied at the LO port 12 of a mixer 13, various cross products of the RF and LO signals will be produced at the mixer's output A, due to the harmonics of the LO signal. Generally, the RF input contains, even after some filtering, not only the desired signal band, but also other unwanted signals, or spurious. Mostly, the spuriouses stem from other communication networks or other sources but it could be possible that they come from the same communication network. This happens if the ratio $\xi = \omega_{CBW} / \omega_{LO}$ is not very small, where ω_{CBW} is the channel bandwidth. It can be shown that when $\xi = 2$ one has the worst scenario in which the neighboring channels become spuriouses because they are exactly at the odd harmonics of the LO, i.e., 3 ω_{LO}, 5 ω_{LO}, ... After mixing, these spuriouses are converted, same as the desired signal, down to the IF band (cf. Fig. 2C), thereby corrupting or even overwhelming the desired signal. This is the reason why the spurious response remains an obstacle to improvement, even for today's mixers.

It is thus an objective of the present invention to improve current mixers and receivers based thereon.

SUMMARY OF THE INVENTION

This obstacle described above is removed with the invention of the spurious-reject mixers described and claimed herein.

A mixer in accordance with the present invention is claimed in claim 1.

Various advantageous embodiments are claimed in claims 2 through 11.

A method in accordance with the present invention is claimed in claim 12.

Various advantageous methods are claimed in claims 13 through 22.

A mixer according to the present invention is particularly well suited for use in a receiver. A receiver in accordance with the present invention is claimed in claim 23.

An advantageous receiver embodiment is claimed in claim 24.

Immediate benefits of this invention are significantly better performance, much lower cost, strong competitiveness, etc.

Other advantages of the present invention are addressed in connection with the detailed embodiments.

Brief description of the drawings

For a more complete description of the present invention and for further objects and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1	is a conventional RF mixer.
FIG. 2A	is a diagram depicting a typical RF signal with two spuriouses.
FIG. 2B	is a diagram depicting the LO frequency and its harmonics.
FIG. 2C	is a diagram depicting the corruption of the signals of the three bands after down conversion (zero IF assumed).
FIG. 3	is a diagram depicting a square wave LO signal, as used in connection with mixers according to the present invention.
FIG. 4A	is a schematic block diagram depicting a first spurious-reject mixer, according to the present invention.
FIG. 4B	is a diagram depicting three square wave LO signals, as used in connection with a mixers of Fig. 4A.
FIG. 5	is a diagram depicting another square wave LO signal, as used in connection with mixers according to the present invention.
FIG. 6A	is a schematic block diagram depicting a second spurious-reject mixer, according to the present invention.
FIG. 6B	is a diagram depicting three square wave LO signals, as used in connection with a mixers of Fig. 6A.
FIG. 7	is a schematic block diagram depicting a third spurious-reject mixer, according to the present invention.
FIG. 8	is a schematic block diagram depicting a receiver, according to the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

The present invention is based on the following principle. The mixers according to the present invention explore the existing cross products of the harmonics of the LO square signal in standard mixers, and generate exactly these products for cancellation. In order to avoid "direct feedthrough", the output of the mixer is sensed as a differential signal, i.e., a signal that is symmetrical with respect to 0. Therefore, the LO square wave toggles between -1 and +1, as shown in Fig.3.

The Fourier series of the waveform of Fig. 3 is given by:

$$S_{LO}(t) = \frac{4}{\pi}(\sin \omega_{LO}t + \frac{1}{3}\sin 3\omega_{LO}t + \frac{1}{5}\sin 5\omega_{LO}t + ...) \qquad (1)$$

where $\omega_{LO} = 2\pi/T$, and T is the period of the square wave. In equation (1), a 50% duty cycle is assumed. For the spurious-reject mixers, according to the present invention, it is important to note that the amplitude of the n-th harmonic of the LO signal is n times smaller than the amplitude of the fundamental, as indicated by equation (1). For the sake of simplicity, one first expresses the RF input as $S_{RF}(t)$. After the multiplication, the result at point A of the mixer is given by

$$S_A(t) = \frac{4}{\pi}S_{RF}(t)(\sin \omega_{LO}t + \frac{1}{3}\sin 3\omega_{LO}t + \frac{1}{5}\sin 5\omega_{LO}t + ...) \qquad (2)$$

Now a situation is considered in which the RF input is:

$$S_{RF}(t) = A\sin(\omega_{LO}t + \vartheta_A) + B\sin(3\omega_{LO}t + \vartheta_B). + C\sin(5\omega_{LO}t + \vartheta_C) + ... \qquad (3)$$

The first term is the desired signal at carrier frequency ω_{LO}, and the second and the third terms are two spuriouses at frequencies $3\omega_{LO}$ and $5\omega_{LO}$, respectively. After mixing, the signal at point A of the mixer is:

$$S_A(t) = \frac{2}{\pi}(A\cos\vartheta_A + \frac{B}{3}\cos\vartheta_B + \frac{C}{5}\cos\vartheta_C + \ldots) + HFT \qquad (4)$$

where HFT stands for high-frequency terms, which can be rejected by the lowpass filter following the mixer. After filtering, the first term in the parenthesis is the down converted signal, while the second and third terms are the spurious responses due to the third and fifth harmonics of the LO signal. In the frequency domain, these two unwanted terms would fall in the IF band (zero frequency in Fig. 2C), thereby reducing the signal-to-noise (S/n) ratio of the receiver and worsening the bit error rate, since bits transmitted in the desired band cannot be discriminated from bits transmitted in the other bands. Although, there will be some kind of filtering to attenuate these spuriouses before they enter into the mixer, unfortunately, any realistic filters can only provide finite attenuation to these spuriouses. Because of the lack of knowledge about these spuriouses, i.e., B, ξ_B, C, ξ_C, and so forth, no remedy or solution is available so far, and the spurious response in a mixer has long been an obstacle to the effort to improvement of the existing mixers. Due to finite transit band of a filter, in general the spurious around the third and the fifth harmonics of the LO signal are the most troublesome ones, and they might be even larger than the desired signal at the mixer's input, even after the filtering.

This is the motivation to the invention to be described and claimed herein. With the new, inventive mixers, the troublesome terms can be eliminated completely from the mixer's output. For the sake of simplicity, yet without loss of generality, the inventive spurious-reject mixer will be disclosed with two embodiments that eliminate the second and third terms in the parenthesis of the equation (4).

Note that the method described in these embodiments can be extended to eliminate other remaining and smaller terms, but the complexity will increase as more unwanted inter-modulation products are to be eliminated.

In Fig. 4A, a first spurious-reject mixer 40, according to the present invention, is shown. The mixer 40 comprises three standard mixers 41, 42, and 43 in this example. In general, a total of n standard mixers are required if the first n-1 unwanted terms in the parenthesis of the equation (4) are to be eliminated. An RF signal $S_{RF}(t)$ is applied to the RF ports 44, 45, and 46 of all three standard mixers 41, 42, and 43, while the LO signals for each standard mixer 41, 42, and 43 are different. In other words, all standard mixers of the mixer 40 have one common input 50. The LO signals are LO1, LO2, and LO3, respectively. The signal LO1 is applied to the port 47, the signal LO2 is applied to the port 48, and the signal LO3 is applied to the port 49. That is, each standard mixer 41, 42, 43 has an individual LO port 47, 48, 49, respectively. Denoting the periods of the signals LO1, LO2 and LO3 by T1, T2 and T3 (cf. Fig. 4B), these signals must have the following relationship:

$$T2 = T1/3$$
$$T3 = T1/5 \qquad (5)$$

and they must have zero phase at t=0 as well, as shown in Fig. 4B. This makes sure that the frequency of the signal LO2 is three times, and the frequency of the signal LO3 is five times, the frequency of the signal LO1, in order to enable a simple realization.

According to the present invention, all LO signals are square wave signals. Now, equations (2) and (4) are still valid for the upper standard mixer 41 in Fig.4A. The results of the other two standard mixers 42 and 43, at points B and C, respectively, can be written similarly as:

$$S_B(t) = \frac{4}{\pi} S_{RF}(t)(\sin 3\omega_{LO}t + \frac{1}{3}\ \sin 9\omega_{LO}t + \frac{1}{5}\ \sin 15\omega_{LO}t + ...)$$
$$S_C(t) = \frac{4}{\pi} S_{RF}(t)(\sin 5\omega_{LO}t + \frac{1}{3}\ \sin 15\omega_{LO}t + \frac{1}{5}\ \sin 25\omega_{LO}t + ...) \tag{6}$$

Again, the RF input is given by the equation (3). Substituting in above equations by the equation (3) yields:

$$S_B(t) = \frac{2}{\pi} B \cos\vartheta_B + HFT$$
$$S_C(t) = \frac{2}{\pi} C \cos\vartheta_C + HFT \tag{7}$$

Now, if the output signal $S_B(t)$ of the standard mixer 42 in the middle is attenuated by a factor of 3, and the output signal $S_C(t)$ of the lower standard mixer 43 by a factor of 5, and if the output signals $S_B(t)$ and $S_C(t)$ are then subtracted from the output signal $S_A(t)$ of the upper standard mixer 41, the result $S_D(t)$ at point D becomes:

$$S_D(t) = \frac{2}{\pi} B \cos\omega\vartheta_A + HFT \tag{8}$$

The subtraction is carried out by an adder 51, the output signals $S_B(t)$ and $S_C(t)$ having a negative sign. It is seen that the second and third terms,

$$2B\cos\vartheta_B/(3\pi)$$

and

$$2C\cos\vartheta_C/(5\pi),$$

which are present in the output signal $S_A(t)$ of the upper standard mixer 41 at point A

(equation (4)), disappear completely from the output signal $S_D(t)$ of the new mixer 40 at point D, i.e., they are fully eliminated or rejected. All higher frequency terms (HFTs) can be suppressed by a subsequent lowpass filter 52, leaving only the desired signal at the mixer output 53:

$$S_{IF}(t) = \frac{2A}{\pi}\cos\vartheta_A \qquad (9)$$

It is thus proven that the new mixer 40, as depicted in Fig. 4A, completely rejects spurious and thus is indeed a spurious-reject mixer.

A mixer in accordance with the first embodiment can be used in cellular telephone technology for heterodyning an incoming radio frequency (RF) cellular telephone signal down to an intermediate frequency, for example.

Another mixer, according to the present invention, just has a second mixer in addition to a first mixer, since this mixer is designed to eliminate the 3rd order harmonic only. The mixer is designed to process an input signal S_{RF} (t) having a carrier frequency (ω_{RF}) defining a desired band and a side band that falls into the 3rd harmonic of a first local oscillator signal LO1. The mixer comprises a main input for receiving the input signal S_{RF} (t), and a first standard mixer having a first mixer input, a first local oscillator input and a first mixer output. The first mixer input is connectable to the main input and the first local oscillator input is connectable to a source providing the first local oscillator signal LO1 having a frequency ω_{LO} close to or equal to the carrier frequency ω_{RF}. The first standard mixer performs a multiplication of the input signal S_{RF} (t) and the first local oscillator signal LO1 in order to provide a first output signal S_A (t) at the first mixer output. It further comprises a second standard mixer having a second mixer input, a second local oscillator input, and a second mixer output. The second mixer input is connectable to the main input and the second local oscillator input is connectable to a source that provides a second local oscillator signal LO2 with the frequency $n\omega_{LO}$. The

second standard mixer performs a multiplication of the input signal $S_{RF}(t)$ and the second local oscillator signal LO2 in order to provide a second output signal $S_B(t)$ at the second mixer output B. The mixer further comprises means for weighing the second output signal $S_B(t)$ with a coefficient -1/3 in order to provide a weighed second output signal. An adder is provided that performs an addition of the first output signal $S_A(t)$ and the weighed second output signal $-1/3\ S_B(t)$.

The first local oscillator signal LO1 and the second local oscillator signal LO2 are square waves.

Yet another mixer 60, according to the present invention, is now described in connection with Fig. 5, Fig.6A and Fig 6B. The mixer 60 is referred to as quadrature mixer, as will be explained in the following paragraphs.

In modern communication, quadrature mixers are extensively used to down convert frequency or phase modulated signals. A quadrature mixer consists of two identical standard mixers (also known as inphase channel or I-channel and quadratur-channel or Q-channel), thereby the phases of the two LO signals are in quadrature. To reduce the noises, again, both LO signals have to be square waves with 50% duty cycle. A square wave which is in quadrature to that in Fig. 3 is shown in Fig. 5. Similarly, the Fourier series of this waveform is given by the following equation:

$$S_{LO}(t) = \frac{4}{\pi}(\cos\omega_{LO}t - \frac{1}{3}\cos 3\omega_{LO}t + \frac{1}{5}\cos 5\omega_{LO}t - \ldots) \qquad (10)$$

Comparing the equation (10) with the equation (1), it is seen that both equations are the same except (i) the fundamental and harmonics are cos rather than sin functions, and (ii) the signs of the 2nd, 4th, 6th, ... terms are negative. Consequently, a spurious-reject mixer in quadrature to its counterpart in Fig. 4A can be obtained by employing the LO

signals shown in Fig. 6B and simply changing the coefficients of the second standard mixer 62 from -1/3 to +1/3.

The mixers can either be standard mixers followed by a special unit that applies appropriate coefficients (e.g., -1/3 in case of the first embodiment, or +1/3 in case of the quadrature embodiment) to the multiplication, or a special mixer can be employed where the multiplication of the input signal $S_{RF}(t)$ and the LO signal (e.g., LO1) is performed such that the respective coefficient is applied in this multiplication. In Figs. 4A and 6A, there are special units 54, 55 and 74, 75, respectively, depicted that are designed to apply the respective coefficient. It is also conceivable, that the LO signals come with the respective coefficient. In this case, the LO2 signal for example should have a coefficient of –1/3.

The mixers employed in connection with the present invention provide for a down conversion of the received (RF) input signal. This down conversion is achieved by a multiplication operation where the received (RF) input signal is multiplied with a local oscillator signal (LO). To achieve this mixing function, the local oscillator (LO) signal runs at or near the incoming carrier frequency of the desired band. The difference between the LO signal and input signal frequency results in the intermediate frequency (IF).

According to the present invention, either there are as many single local oscillator sources as there are standard mixers (e.g., three mixers and three LO sources), or there is one generator providing a plurality of oscillator signals to a combination logic. This combination logic combines the plurality of oscillator signals to generate the desired local oscillator signals.

One embodiment where two local oscillator sources are employed is depicted in Fig. 7. The mixer 90 comprises two standard mixers being part of a unit 91.There are two local oscillators 93 and 94. The first local oscillator 93 outputs a signal LO1 and the second

local oscillator 94 outputs a signal LO2, as depicted in Fig. 7. In addition, the mixer 90 has an input 92 for receiving a input signal $S_{RF}(t)$ and an output 95 for providing an output signal.

A radio frequency signal receiver 80, comprising another arrangement in accordance with the present invention, is depicted in Fig. 8. The receiver 80 comprises a mixer 84, a generator 86 providing a plurality oscillator signals (in the present example three different oscillator signals are provided, hence there are three connections from the generator 86 to the combination logic 87), and a combination logic 87 to obtain the required LO signals LO1, LO2, and LO3. The receiver 80 further comprises an antenna 81 followed by a front-end bandpass filter 82. This filter 82 may be employed in order to filter unwanted 'image' signals before reaching the mixer 84. The front-end bandpass filter 82 is followed by a low noise amplifier 83 (LNA) that provides for an amplification of the received RF signal. Since the mixer 84 directly follows the low noise amplifier 83, it very much determines the performance of the overall receiver system 80. At the output D of the mixer 84, a filter 85 – e.g., a low-pass filter - may be situated.

A data processing unit 89 may be connected to the output 88 of the filter 85. The data processing unit 89 performs a post processing of the information signal (preferably digital data) that was carried in the desired band received via the antenna 81. The data processing unit 89 may comprise some form of microprocessor or digital signal processing (DSP) engine. The receiver system 80 could be part of the receive path of a GSM, Bluetooth or UMTS cellular telephone, for example.

It has been shown and described in connection with the mixer circuits 40 and 60 of Figs. 4A and 6A that adding one additional mixer to a conventional mixer gives it the power to reject one more spurious due to one harmonic of the LO signal. In general, adding n additional mixers to a conventional mixer of Fig. 1, for example, enables the resultant mixer to reject n spuriouses around a total of n harmonics of the LO signal.

As expected, the resultant mixer becomes more complex as more spuriouses are to be rejected. As the circuit is getting more complex, the proper multiplying coefficients may not be found so easily by inspection, as above, but by solving equations. On the other hand, the higher order harmonics of a square wave have lower amplitudes, and spurious at higher frequencies can be sufficiently suppressed by a filter. This calls for a trade-off. Up to which order of the harmonics of the LO signal the spurious around depends on the application and the specific situation.

Nevertheless, it is deemed that the mixer embodiments in Figs. 4A and 6A are reasonable and adequate for most applications. This is for at least two reasons: First, the cross-product falling in the IF band due to the n-th harmonic of the LO signal is inversely proportional to n. Secondly, a bandpass or lowpass filter can provide more attenuation to a signal as its frequency apart further from the center frequency of the bandpass filter, or the corner frequency of a lowpass filter. Like the spurious, the input noise spectra within the IF band at the odd harmonics of the LO signals fall in the forbidden band after mixing. Fortunately, they can also be rejected by the inventive spurious-reject mixers.

It is an advantage of the present invention, that the mixers can easily be implemented as integrated circuits. They can thus be relatively inexpensive to manufacture. Well suited is CMOS technology. The inventive concept can be applied to fully-integrated CMOS receivers, for example. Bipolar transistors, however, can be used as well.

The present invention can be applied to heterodyne radio frequency receivers. Mixers of the variety to which the present invention pertains, have many potential practical applications, including integrated circuits and modules for radio frequency receivers, and other wireless communications products. They are, for instance, employed in single side-band mixers and quadrature demodulators and modulators.

It is appreciated that various features of the invention which are, for clarity, described in the context of separate embodiments may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment may also be provided separately or in any suitable subcombination.

In the drawings and specification there has been set forth preferred embodiments of the invention and, although specific terms are used, the description thus given uses terminology in a generic and descriptive sense only and not for purposes of limitation.

CLAIMS

1. Apparatus (40; 60; 80; 90) for processing an input signal (S_{RF} (t)) with a carrier frequency (ω_{RF}) defining a desired band and at least a side band being having a side band frequency ($n\omega_{LO}$) that is higher than the carrier frequency (ω_{RF}), the apparatus (40; 60; 80; 90) comprising
   - a main input (50; 70; 79; 92) for receiving said input signal (S_{RF} (t)),
   - a first mixer (41; 61) having a first mixer input (44; 64), a first local oscillator input (47; 67), and a first mixer output (A), the first mixer input (44; 64) being connectable to the main input (50; 70; 79; 92) and the first local oscillator input (47; 67) being connectable to a source (86, 87; 93) providing a first local oscillator signal (LO1) having a frequency (ω_{LO}) close to or equal to the carrier frequency (ω_{RF}), the first mixer (41; 61) performing a multiplication of said input signal (S_{RF} (t)) and said first local oscillator signal (LO1) in order to provide a first output signal (S_A (t)) at the first mixer output (A),

   the apparatus (40; 60; 80; 90) being characterized in that it further comprises
   - at least a second mixer (42; 62) having a second mixer input (45; 65), a second local oscillator input (48; 68), and a second mixer output (B), the second mixer input (45; 65) being connectable to the main input (50; 70; 79; 92) and the second local oscillator input (48; 68) being connectable to a source (86, 87; 94) providing a second local oscillator signal (LO2) with the side band frequency ($n\omega_{LO}$), the second mixer (42; 62) performing a multiplication of said input signal (S_{RF} (t)) and said second local oscillator signal (LO2) in order to provide a second output signal (S_B (t)) at the second mixer output (B),
   - means for performing a superposition of the first output signal (S_A (t)) and the second output signal (S_B (t)),

   whereby the first local oscillator signal (LO1) and the second local oscillator signal (LO2) are square waves.

2. Apparatus (40; 60; 80; 90) of claim 1, wherein the second mixer (42; 62) applies a negative or a positive coefficient (1/3; -1/3; 1/n; -1/n) when performing the multiplication of said input signal (S_{RF} (t)) and said second local oscillator signal (LO2).

3. Apparatus (40; 60; 80; 90) of claim 1 or 2, wherein the means for performing a superposition of the first output signal and the second output signal (S_B (t)) are realized as an adder (51; 71).

4. Apparatus (40; 60; 80; 90) of claim 1, 2 or 3, wherein the desired band carries an information signal, preferably digital data, modulated on to the carrier signal with the carrier frequency (ω_{RF}).

5. Apparatus (40; 60; 80; 90) of one of the preceding claims, wherein the side band frequency ($n\omega_{LO}$) is an odd harmonic of the carrier frequency (ω_{RF}).

6. Apparatus (40; 60; 80; 90) of one of the preceding claims, further comprising a low-pass filter (LPF; 52; 72; 85) at the output side of the apparatus (40; 60; 80; 90).

7. Apparatus (40; 60; 80; 90) of one of the preceding claims, wherein, in order to avoid direct feed-through, the output of the apparatus (40; 60; 80; 90) is sensed as a differential signal.

8. Apparatus (40; 60; 80; 90) of one of the preceding claims, wherein the period (T1) of the first local oscillator signal (LO1) and the period (T2) of the second local oscillator signal (LO2) have the following relationship: T2 = T1/3.

9. Apparatus (40; 60; 80; 90) of one of the preceding claims, wherein the first local oscillator signal (LO1) and the second local oscillator signal (LO2) have zero phase at t=0.

10. Apparatus (60; 80; 90) of one of the claims 1 through 8, wherein the first local oscillator signal (LO1) and the second local oscillator signal (LO2) have phases being in quadrature.

11. Apparatus (40; 60; 80; 90) of one of the preceding claims, wherein the square waves have a 50% duty cycle.

12. Method for processing an input signal ($S_{RF}(t)$) having a carrier frequency (ω_{RF}) defining a desired band and at least one side band frequency ($n\omega_{LO}$) defining a side band, whereby by the side band frequency ($n\omega_{LO}$) is higher than the carrier frequency (ω_{RF}), comprising the steps:
   - receiving said input signal ($S_{RF}(t)$),
   - providing a first local oscillator signal (LO1) having a frequency (ω_{LO}) close to or equal to the carrier frequency (ω_{RF}),
   - performing a multiplication of said input signal ($S_{RF}(t)$) with said first local oscillator signal (LO1) in order to provide a first output signal ($S_A(t)$),
   - providing a second local oscillator signal (LO2) with the side band frequency ($n\omega_{LO}$)
   - performing a multiplication of said input signal ($S_{RF}(t)$) and said second local oscillator signal (LO2) in order to provide a second output signal ($S_B(t)$),
   - performing a superposition of the first output signal ($S_A(t)$) and the second output signal ($S_B(t)$),

   wherein the first local oscillator signal (LO1) and the second local oscillator signal (LO2) are square waves.

13. Method of claim 12, wherein a negative or a positive coefficient (1/3; -1/3; 1/n; -1/n) are applied when performing the multiplication of said input signal ($S_{RF}(t)$) and said second local oscillator signal (LO2).

14. Method of claim 12 or 13, wherein the superposition is performed by means of an adder (51; 71).

15. Method of claim 12, 13 or 14, wherein the desired band carries an information signal, preferably digital data, modulated on to the carrier signal with the carrier frequency (ω_{RF}).

16. Method of one of the claims 12 through 15, wherein the side band frequency ($n\omega_{LO}$) is an odd harmonic of the carrier frequency (ω_{RF}).

17. Method of one of the claims 12 through 16, employing a low-pass filter (LPF; 52; 72; 85) at the output side.

18. Method of one of the claims 12 through 17, wherein the output is sensed as a differential signal.

19. Method of one of the claims 12 through 18, wherein the period (T1) of the first local oscillator signal (LO1) and the period (T2) of the second local oscillator signal (LO2) have the following relationship: T2 = T1/3.

20. Method of one of the claims 12 through 19, wherein the first local oscillator signal (LO1) and the second local oscillator signal (LO2) have zero phase at t=0.

21. Method of one of the claims 12 through 19, wherein the first local oscillator signal (LO1) and the second local oscillator signal (LO2) have phases being in quadrature.

22. Method of one of the claims 12 through 21, wherein the square waves have a 50% duty cycle.

23. Receiver, preferably a heterodyne radio frequency receiver, comprising an apparatus (40; 60; 80; 90) according to one of the claims 1 through 11, said apparatus (40; 60; 80; 90) being part of a chain of circuits (82, 83, 85, 89) that processes the input signal ($S_{RF}(t)$) to convert it to a low frequency intermediate frequency signal ($S_{IF}(t)$).

24. Receiver of claim 23, being part of a Global System for Mobile communication (GSM) system, a Blue tooth system, or a Universal Mobile Telephony System.

ABSTRACT

Apparatus (40) for processing an input signal ($S_{RF}(t)$) with a carrier frequency (ω_{RF}) defining a desired band and at least a side band being defined by a side band frequency ($n\omega_{LO}$) that is higher than the carrier frequency (ω_{RF}). The apparatus (40) comprises a main input (50) for receiving said input signal ($S_{RF}(t)$), and a first standard mixer (41) having a first mixer input (44), a first local oscillator input (47), and a first mixer output (A). The first mixer input (44) is connected to the main input (50) and the first local oscillator input (47) is connected to a source that provides a first local oscillator signal (LO1) having a frequency (ω_{LO}). This frequency (ω_{LO}) is close to or equal to the carrier frequency (ω_{RF}). The first standard mixer (41) performs a multiplication of the input signal ($S_{RF}(t)$) and the first local oscillator signal (LO1) to provide a first output signal ($S_A(t)$) at the first mixer output (A). The apparatus (40) further comprises a second mixer (42) with a second mixer input (45), a second local oscillator input (48), and a second mixer output (B). The second mixer input (45) is connected to the main input (50) and the second local oscillator input (48) is connected to a source that provides a second local oscillator signal (LO2) with the side band frequency ($n\omega_{LO}$). The second mixer (42) performs a multiplication of the input signal ($S_{RF}(t)$) and the second local oscillator signal (LO2) to provide a second output signal ($S_B(t)$) at the second mixer output (B). There are means for superposition (51) of the first output signal ($S_A(t)$) and the second output signal ($S_B(t)$). The first local oscillator signal (LO1) and the second local oscillator signal (LO2) are square waves. The apparatus (40) may comprise a third source that provides a third local oscillator signal (LO3). This third local oscillator signal (LO3) can be fed into a mixer (43) where a multiplication is performed. If such a third source is employed, the means for superposition (51) perform a superposition of three signals ($S_A(t)$), ($S_B(t)$), and ($S_C(t)$).

(Fig. 4A)

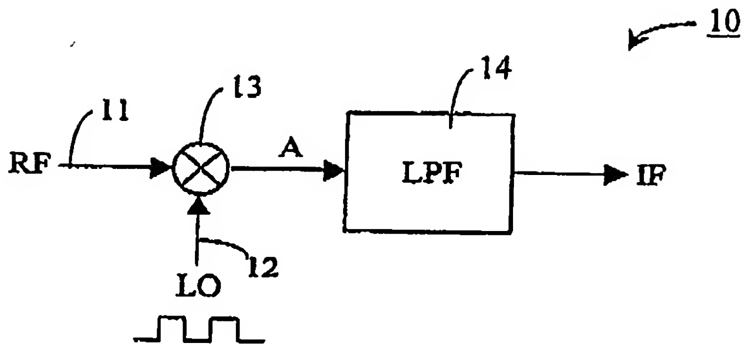

Fig. 1

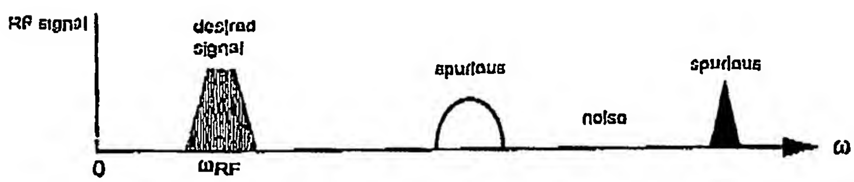

Fig. 2A

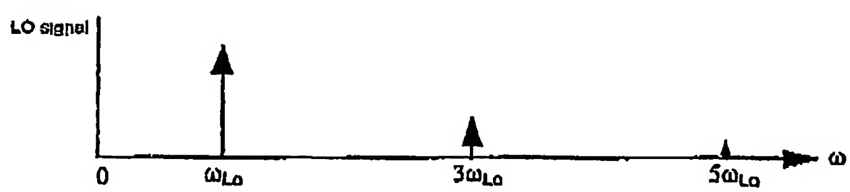

Fig. 2B

Fig. 2C

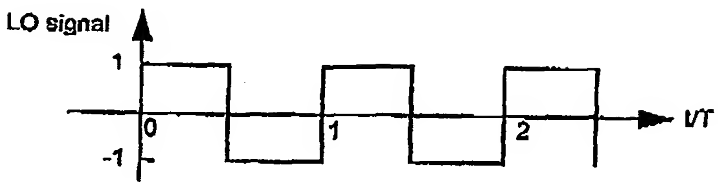
LO signal
1
-1
0
1
2
t/T

Fig. 3

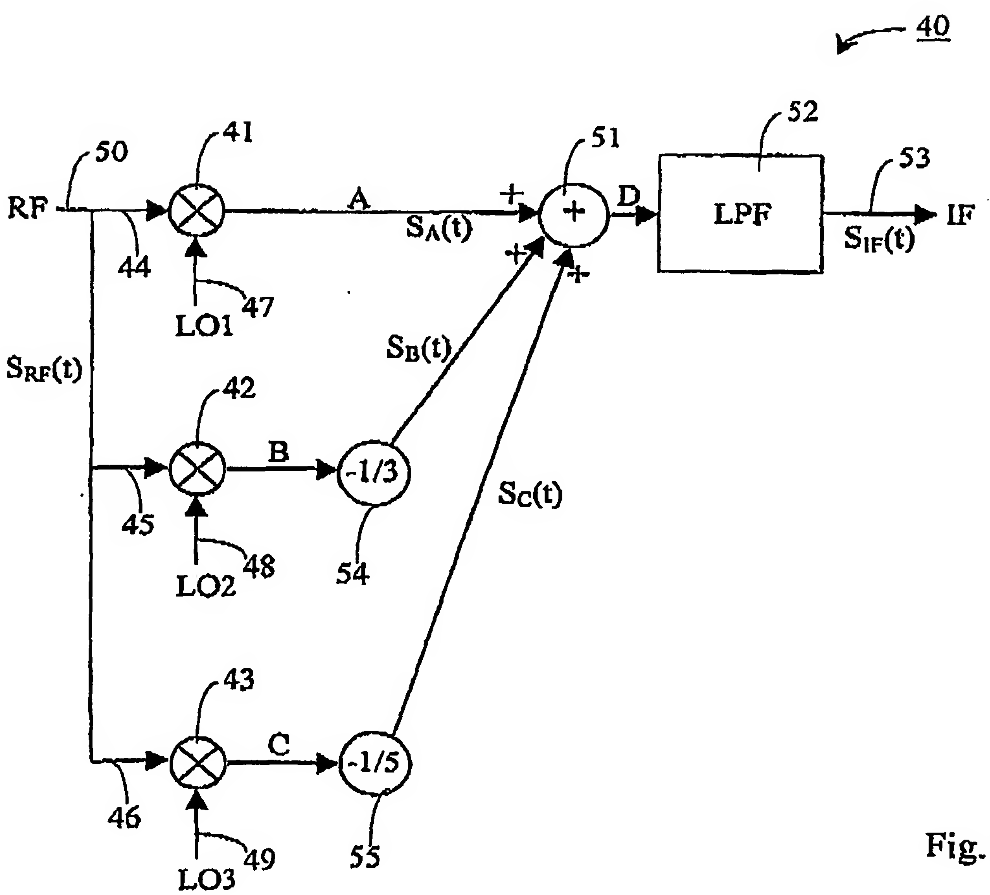
40
RF
50
44
41
47
LO1
A
$S_A(t)$
+
51
+
D
LPF
52
53
$S_{IF}(t)$
IF
$S_{RF}(t)$
42
45
48
LO2
B
-1/3
54
$S_B(t)$
+
+
$S_C(t)$
43
46
49
LO3
C
-1/5
55

Fig. 4A

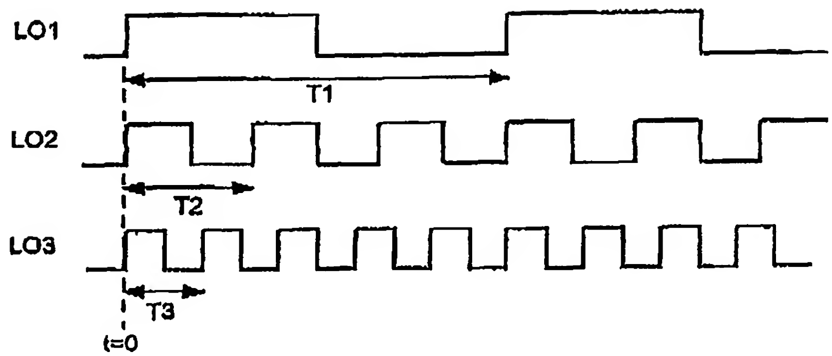

Fig. 4B

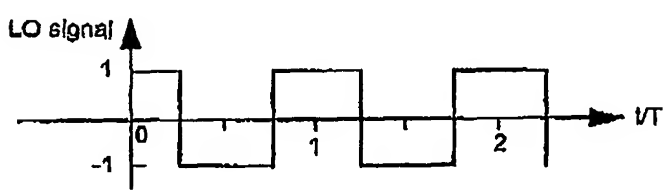

Fig. 5

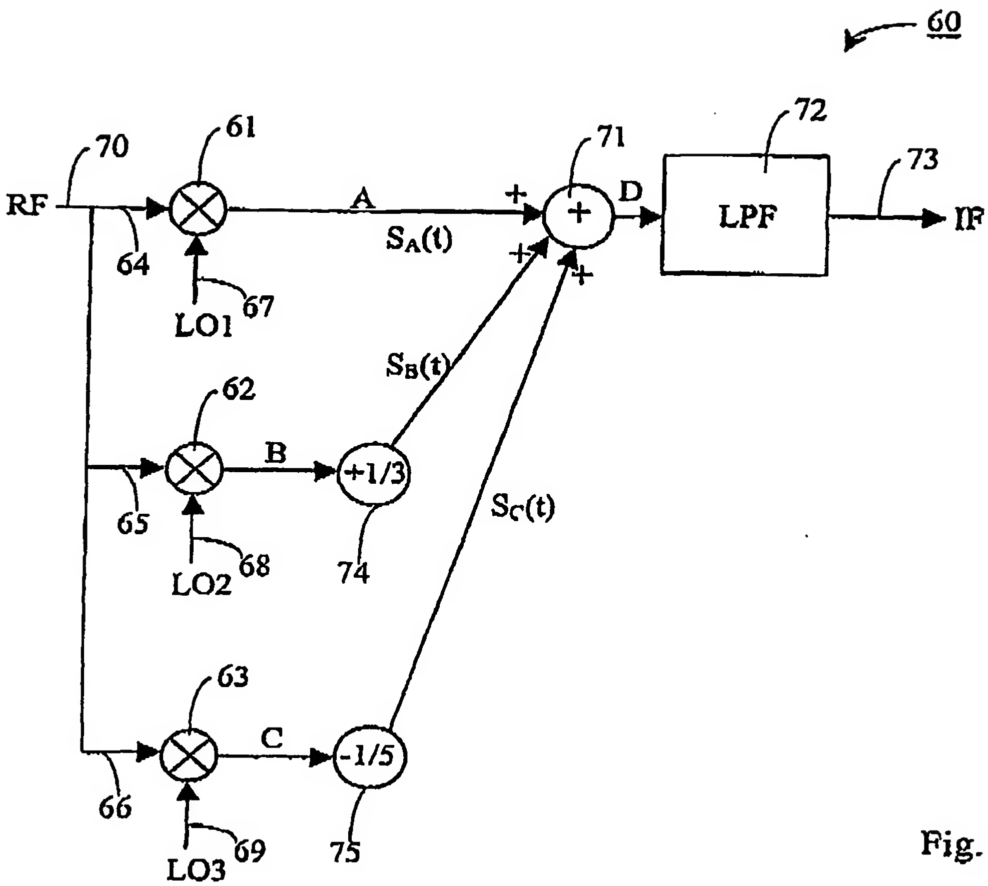
60
RF
70
61
71
72
73
LPF
IF
A
D
$S_A(t)$
64
67
LO1
$S_B(t)$
62
B
+1/3
65
68
LO2
74
$S_C(t)$
63
C
-1/5
66
69
LO3
75

Fig. 6A

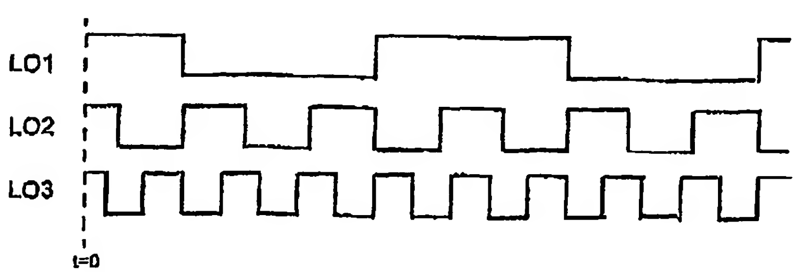
LO1
LO2
LO3
t=0

Fig. 6B

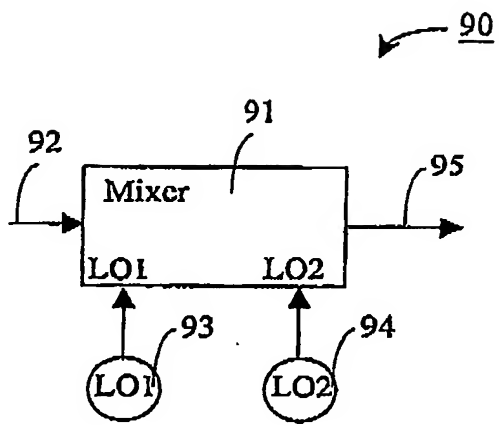
90
91
92
95
Mixer
LO1
LO2
93
94
LO1
LO2

Fig. 7

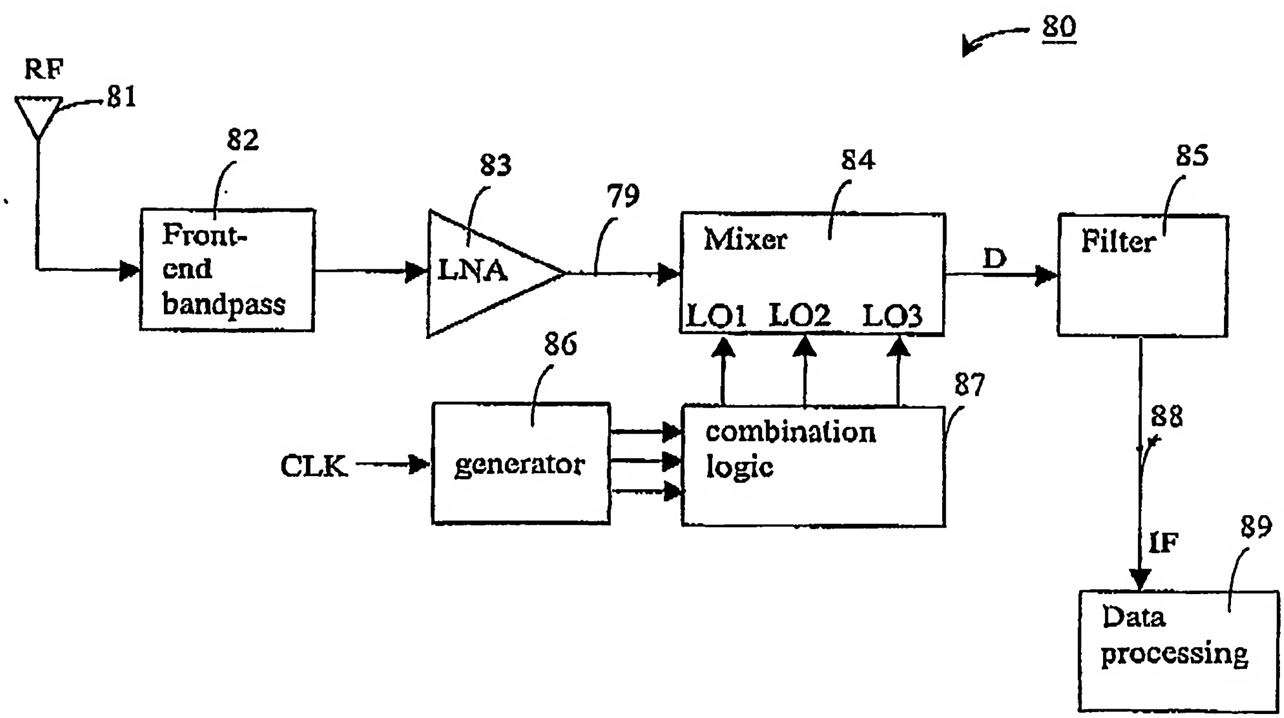
80
RF
81
82
83
84
85
79
Front-end bandpass
LNA
Mixer
D
Filter
LO1 LO2 LO3
86
87
88
CLK
generator
combination logic
IF
89
Data processing

Fig. 8